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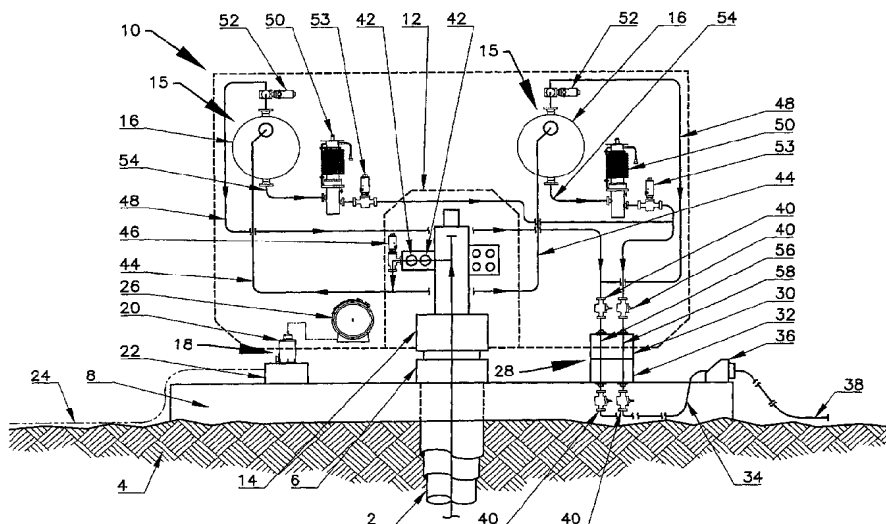
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— as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designations AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI,

[Continued on next page]

(54) Title: SINGLE WELL DEVELOPMENT SYSTEM



(57) Abstract: A single well development system has a base structure (8) through which the well is drilled and completed by means of a wellhead (6). A retrievable Christmas tree module (10) containing a Christmas tree (12) connected to a wellhead connector (14) is mounted on the base structure (8) by the wellhead connector (14) so as to receive well fluid from the wellhead. The module (10) contains two fluid processing separators (16) for processing fluid received from the well via the wellhead (6) and the Christmas tree (12). In a modification, additional modules are mounted on the base structure and each additional module has a fluid processing separator (16), and the Christmas tree module routes production fluid to the separators via the base structure (8).



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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

## SINGLE WELL DEVELOPMENT SYSTEM

The present invention relates to the economically viable extraction of hydrocarbon reserves from a single sub-sea well.

Existing single well developments are generally connected to a host facility which is often located remotely from the well, where processing equipment is situated. In situations in which the well has insufficient drive or pressure, pressure boosting of production fluid by means of a pump is required. The flow may suffer from one of a number of flow assurance problems such as: (i) slug flow (flow containing slugs of gas and/or liquid); (ii) the formation of hydrates; (iii) corrosion; and (iv) sand precipitation. The provision of separate structures for treating the flow from a single well and the consequent requirement for interconnections between the wellhead and the structures may not be economically viable when only a single well is concerned.

The object of the invention is to overcome at least some of the above-mentioned problems and provide a means by which a single sub-sea well field can be economically developed.

Thus according to the invention there is provided a single well development system comprising:

- (i) a base structure through which the well is drilled and completed by means of a wellhead;
- (ii) a retrievable christmas tree module including a christmas tree and connecting means for connecting the christmas tree module to the wellhead so as to receive well fluid therefrom; and
- (iii) fluid processing means for processing fluid received from the well via the wellhead and christmas tree and which is connected closely above the base structure.

The christmas tree module is primarily supported by means of its connection to the wellhead. The base structure and/or the christmas tree module may include supplementary support means for the christmas tree module which is independent of the wellhead connecting means.

The system may include at least one additional retrievable module. At

least one said module may include at least part of the fluid processing means. The fluid processing means may accordingly form part of the christmas tree module and/or one or more of the additional retrievable modules.

Conveniently the system includes at least one fluid connector, the or  
5 each fluid connector comprising first and second engageable portions, the first portion forming part of one said retrievable module and the second portion forming part of the base structure. The engageable portions may each include plural passageways for separate fluid flows and may form part of the connecting means for connecting the christmas tree to the wellhead.

10 The retrievable christmas tree module may include a power and/or control pod. At least one said retrievable module may include a power and/or control pod in which case such a pod may not form part of the christmas tree module.

Preferably, the system includes at least one electrical connector, the or  
15 each electrical connector comprising first and second interengageable portions, the first interengageable portion forming part of said retrievable module and the second interengageable portion forming part of the base structure. The first interengageable portion is connected to the power and/or control pod in the appropriate module.

20 The base structure may comprise a drilling template for drilling a well.

The base structure may include means for guiding the at least one retrievable module onto the base structure. In addition, the base structure may have means for supporting the at least one retrievable module. The system may include a plurality of additional retrievable modules, each of which is  
25 connectable to the retrievable module containing the christmas tree via connection means, whereby the module connection means is configured to enable at least one additional retrievable module to be isolated and removed from the base structure without affecting the connection between the christmas tree module and any of the remaining modules of the system. Each module  
30 may include a module based part of the module connection means and the base structure includes a complementary base structure based part of the module connecting means.

The connection means preferably includes fluid connectors as described above for each module. The base structure may include fluid delivery means, such as pipes, for conveying fluid flowing from the christmas tree module to the base structure in separate and/or parallel flows to the plural additional modules.

- 5 The flow of fluid to each such additional module being via the corresponding fluid connector enables the additional module to be isolated from the flow.

The base structure based second engageable portion of the fluid connectors may be connected to a flow line connection for conveying fluid from the base structure to one or more external flow lines.

- 10 The connection means preferably also includes electrical connectors as described above. The base structure may include electrical connection means for conveying electrical power and/or control signals from one or more additional modules to the wellhead tree module. The base structure second interengageable portions of the electrical connectors may be connected to an  
15 integrated service umbilical for receipt by the system of electrical power and/or control signals, injection chemicals for addition to fluids acted on by the system etc.

- Fluid processing means in one or more of the modules may comprise one or more separators, such a gravity separators, hydrocyclones etc. The  
20 flows through which may be controlled by means of flow control valves, preferably electrically actuated which may be adjusted under control of a power and/or control pod. A power and/or control pod in one module may be connected to control components in another module.

- The invention also provides a method of exploiting the output from a  
25 single well, comprising:

- (i) installing a base structure;
- (ii) drilling a well through the base structure;
- (iii) installing a casing string in the drilled well;
- (iv) terminating the casing string with a wellhead;
- 30 (v) connecting a retrievable christmas tree module containing a christmas tree to the wellhead by means of connecting means so as to receive well fluid therefrom;

(vi) providing fluid processing means connected closely above the base structure; and

(vii) processing fluid received from the well via the wellhead and christmas tree with the processing means.

5           The method may also include employing any of the features referred to above.

The invention will now be described by way of example only with reference to the accompanying schematic figures in which:

Figure 1 shows a first system according to the present invention;

10           Figure 2 shows a second system according to the present invention;

Figure 3 shows a third system according to the present invention;

Figure 4 shows a fourth system according to the present invention; and

Figure 5 shows a fifth system according to the present invention.

15           In the Figures, like numerals are used to designate like parts and the description of a particular part applies to correspondingly numbered parts in different Figures unless otherwise stated.

A first system according to the invention is shown in Figure 1. A well string 2 emerges from the seabed 4 and terminates in a wellhead 6 installed through a base structure 8 connected to the seabed 4. A retrievable module 10 containing a christmas tree 12 connected to a wellhead connector 14 is mounted on the base structure 8 by means of the wellhead connector 14 being coupled to the wellhead 6 and possibly by other engagement means not shown.

20           The retrievable module 10 also includes fluid processing means 15 including a minimum of two separators 16 which substantially duplicate each other thus affording component redundancy. The module could alternatively include only one set of processing means components. For the purpose of providing power and control to the module 10, and also transmitting signals therefrom, an electrical connector 18 is provided having first and second complementary interengageable portions 20 and 22 constituting parts of the module 10 and the base structure 8 respectively. An integrated service umbilical 24, for connection to a remote facility is connected to the second

interengageable portion and a power and control pod 26 is connected to the first interengageable portion.

For the purpose of routing fluid(s) away from the module 10, a fluid connector 28 is provided including first and second complementary interengageable portions 30 and 32 constituting parts of the module 10 and the base structure 8 respectively. The second portion 32 being connected by one or more outlet pipes 34 to a flow line connection 36 which is in turn connected to one or more flow lines 38. Isolation valves 40 are incorporated in piping runs leading to the fluid connector 28 which can be closed when its first and second engageable portions are to be separated.

Fluid output from the christmas tree 12 to each separator 16 via separator input pipe 44 is controlled by two failsafe valves 42 and a choke valve 46. A gas output pipe 48 from each separator 16 routes gas through a pressure control valve 52. The gas output pipes 48 communicate with a gas passageway 56 of the first portion 30 of the fluid connector 28. A liquid output pipe 54 from each separator 16 routes liquid therefrom to a pump 50 and flow control valve 53 to a liquid passageway 58 in the first portion 30 of the fluid connector 28. Electrical signals from various sensors (not shown) are routed to the pod 26 which provides electrical signals for controlling the valves, the pumps, etc to control the operation of fluid processing means 15 and in particular the level of the gas/liquid interfaces in the separators 16. Signal/power lines between the components and the pod 26 have been omitted for the sake of clarity.

Figure 2 shows a second system according to the invention in which only one separator 16 is provided in the christmas tree module 60 rather than two. Liquid 62, gas 64, the liquid/gas interface 66 and interface level sensor 68 are shown in the separator 16 in Figure 2. These features have been omitted from Figure 1.

Figure 3 shows a third system according to the invention which differs from that shown in Figure 2 in that the fluid connector 28 and wellhead connector 14 of Figure 2 are replaced by a combined fluid connector and wellhead connector 70 including a first part 72 and a second part 74

comprising parts of the christmas tree module 76 and the base structure 78 respectively. Such a combined connector 70 could be employed in the system shown in Figure 1.

Figure 4 shows a fourth system according to the invention in which fluid  
5 processing means 80 is provided in each of two additional retrievable modules 82 and christmas tree module 84 routes fluid from the christmas tree 12 to a fluid connector 86 comprising first and second portions 88 and 90 forming parts of the christmas tree module 84 and the base structure 92 respectively.

In each additional retrievable module 82, the gas and liquid output pipes  
10 48 and 54 and the input pipe 44 of the separator 16 are connected to a first portion 96 of a fluid connector 94. A second complementary portion 98 of each fluid connector forms part of the base structure 92.

The base structure 92 includes fluid delivery means, in the form of pipes  
15 100, for conveying fluid: (i) from the wellhead tree 12 and fluid connector 86 to the two additional modules 82 and into their separators 16; and (ii) from the separators 16 and fluid connectors 94 to the flow line connection 36.

Isolation valves 40, only some of which are labelled, are provided for closure when the first and second portions of the fluid connectors 86 and 94 are to be separated.

20 The power and control pod 26 of each additional module 82 is connected to a supplementary electrical connector 103 which is connected via transmission means 102, such as wires in the base structure 92 to a christmas tree module electrical connector 104. The supplementary and christmas tree module electrical connectors 103 and 104 are similar to the electrical  
25 connectors 18. Both of the christmas tree module electrical connectors 104 are connected to all appropriate components (e.g. sensors, choke valves etc) in the christmas tree module 84 and accordingly the christmas tree module 84 can be controlled via or by either of the additional modules 82 for example if the other additional module had to be removed for any reason.

30 Figure 5 shows a further system according to the invention which differs from that shown in Figure 4 only in that the fluid connector 86 and wellhead connector 14 are replaced by a combined fluid connector and wellhead

connector 106 comprising first and second portions 108 and 110 constituting parts of the christmas tree module 84 and base structure 112 respectively. The combined connector 106 performs the functions carried out by the fluid connector 86 and the wellhead connector 14 in the system depicted in Figure 4.

5        Although the systems depicted in Figures 4 and 5 employ two additional modules 82, more could be included, connected in a like manner, if required.

Such systems would also be suitable for other environments in which access poses a problem, for example in swampy areas.

10        The modules may form part of the modular system designed by Alpha Thames Limited of Essex, United Kingdom and named AlphaPRIME.

CLAIMS:

1. A single well development system comprising:
  - (i) a base structure (8) through which the well is drilled and completed by  
5 means of a wellhead (6);
  - (ii) a retrievable christmas tree module (10) including a christmas tree (12) and connecting means (14) for connecting the christmas tree module to the wellhead (6) so as to receive well fluid therefrom; and
  - (iii) fluid processing means (15) for processing fluid received from the well  
10 via the wellhead (6) and christmas tree (12) and which is connected closely above the base structure (8).
2. A system as claimed in claim 1, wherein the christmas tree module (10) is primarily supported by means of its connection to the wellhead (8).  
15
3. A system as claimed in claim 1 or 2, wherein the base structure (8) and/or the christmas tree module (10) include supplementary support means for the christmas tree module which is independent of the wellhead connecting means (14).  
20
4. A system as claimed in any preceding claim, including at least one additional retrievable module (82).
5. A system as claimed in any one of claims 1 to 4, including a plurality of  
25 additional retrievable modules (82), each of which is connectable to the retrievable module (84) containing the christmas tree (12) via connection means (86,94), whereby the module connection means is configured to enable at least one additional retrievable module (82) to be isolated and removed from the base structure without affecting the connection between the christmas tree  
30 module (10) and any of the remaining modules of the system.
6. A system as claimed in claim 4 or 5, wherein the fluid processing means

(15) form part of the christmas tree module (10) and/or one or more of the additional retrievable modules (82).

7. A system as claimed in claim 4, 5 or 6, wherein each module (82,84)  
5 includes a module based part (88,96) of the module connection means (86,94) and the base structure includes a complementary base structure based part (90,98) of the module connecting means.

8. A system as claimed in any one of claims 4 to 7, wherein the base  
10 structure (92) includes fluid delivery means (100) for conveying fluid flowing from the christmas tree module (84) to the base structure (92) in separate and/or parallel flows to the at least one additional module (82).

9. A system as claimed in any preceding claim, wherein the retrievable  
15 christmas tree module (10) includes a power and/or control pod (26).

10. A system as claimed in any one of claims 4 to 8, wherein at least one  
said additional retrievable module (82) includes a power and/or control pod (26).

20 11. A system as claimed in claim 9 or 10, wherein a power and/or control pod (26) in one module (82) is connected to control components in another module (84).

25 12. A system as claimed in any one of claims 4 to 11, wherein the base structure includes electrical connection means (103) for conveying electrical power and/or control signals from one or more additional modules (82) to the wellhead tree module (84).

30 13. A system as claimed in any preceding claim, wherein fluid processing means (15) in one or more of the modules comprises one or more separators (16).

14. A system as claimed in claim 13, including at least one flow control valve (52,53) for controlling the flow through at least one said separator (16).

5 15. A system as claimed in claim 9, 10 or 11, wherein the at least one flow control valve (53) are adjusted under control of said power and/or control pod (26).

10 16. A system as claimed in any one of claims 9 to 15, including at least one electrical connector (18), the or each electrical connector comprising first and second interengageable portions (20,22), the first interengageable portion (20) forming part of a said retrievable module (10) and the second interengageable portion (22) forming part of the base structure (8).

15 17. A system as claimed in claim 16, wherein the first interengageable portion (22) of the electrical connector (18) is connected to the power and/or control pod (26) in the appropriate module.

20 18. A system as claimed in claim 16 or 17, wherein the base structure second interengageable portion (22) of the electrical connector (18) is connected to an integrated service umbilical (24).

25 19. A system as claimed in claim 17 or 18, wherein the connection means includes said electrical connector (18).

30 20. A system as claimed in any preceding claim, including at least one fluid connector (28), the or each fluid connector comprising first and second engageable portions (30,32), the first portion (30) forming part of one said retrievable module (10) and the second portion (32) forming part of the base structure (8).

21. A system as claimed in claim 20, wherein the base structure based

second engageable portion (32) of the fluid connector (28) is connected to a flow line connection (34,36) for conveying fluid from the base structure (8) to one or more external flow lines (38).

5 22. A system as claimed in claim 20 or 21, wherein the engageable portions (30,32) each include plural passageways for separate fluid flows and form part of the connecting means (14) for connecting the christmas tree (12) to the wellhead (6).

10 23. A system as claimed in claim 20, 21 or 22, wherein the connection means (86,94) includes said fluid connector for said at least one module.

24. A system as claimed in any preceding claim, wherein at least one said module (10,82) includes at least part of the fluid processing means (15).

15

25. A system as claimed in any preceding claim, wherein the base structure (8) comprise a drilling template for drilling a well.

20 26. A system as claimed in any preceding claim, wherein the base structure (8) includes means for guiding the at least one retrievable module onto the base structure.

27. A system as claimed in any preceding claim, wherein the base structure (8) has means for supporting the at least one retrievable module.

25

28. A method of exploiting the output from a single well, comprising the steps of:

- (i) installing a base structure (8);
- (ii) drilling a well through the base structure (8);
- 30 (iii) installing a casing string (2) in the drilled well;
- (iv) terminating the casing string (2) with a wellhead (6);
- (v) connecting a retrievable christmas tree module (10) containing a

christmas tree (12) to the wellhead (6) by means of connecting means (14) so as to receive well fluid therefrom;

(vi) providing fluid processing means (15) connected closely above the base structure (8); and

- 5 (vii) processing fluid received from the well via the wellhead (6) and christmas tree (12) with the processing means (15).

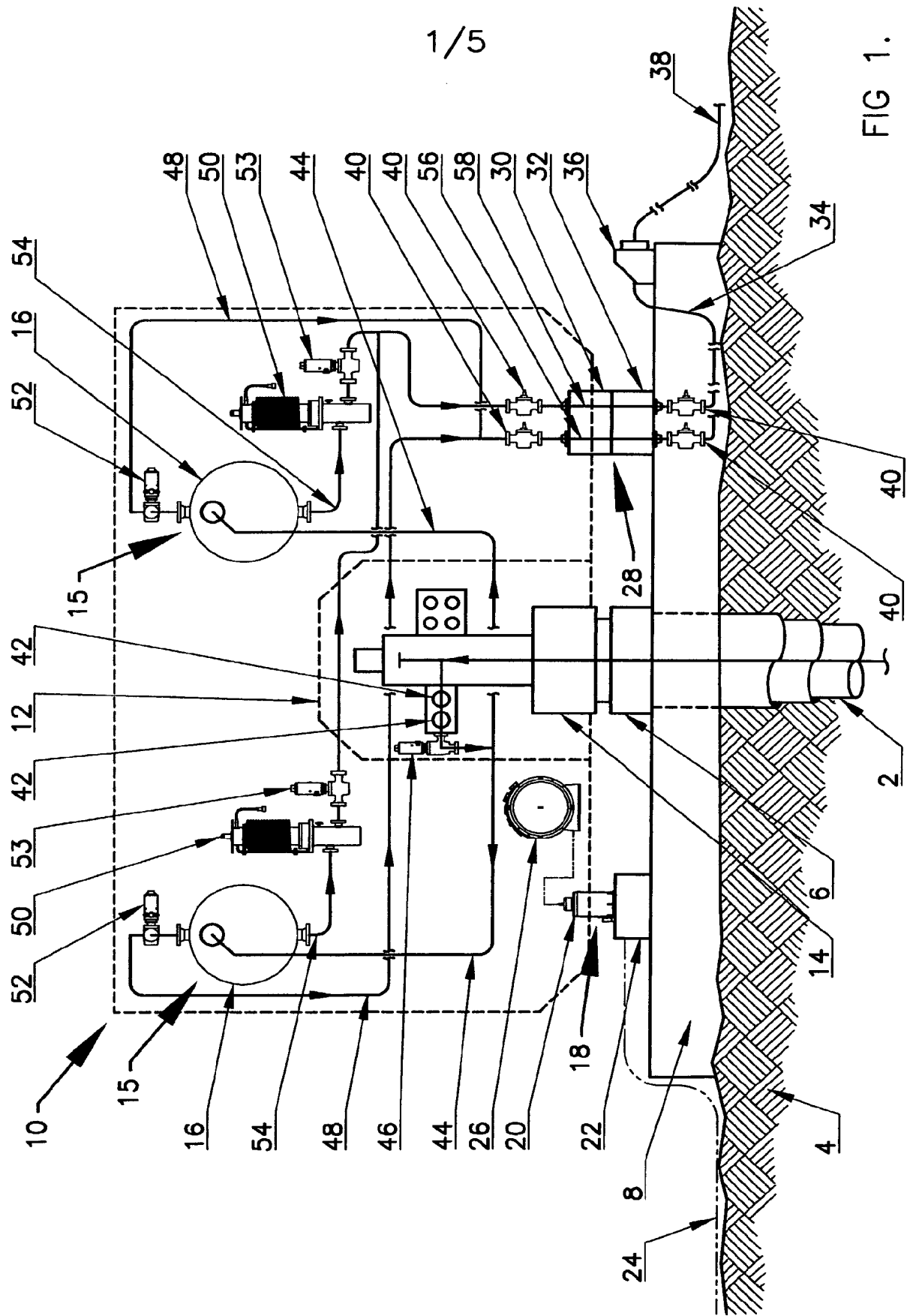


FIG 1.

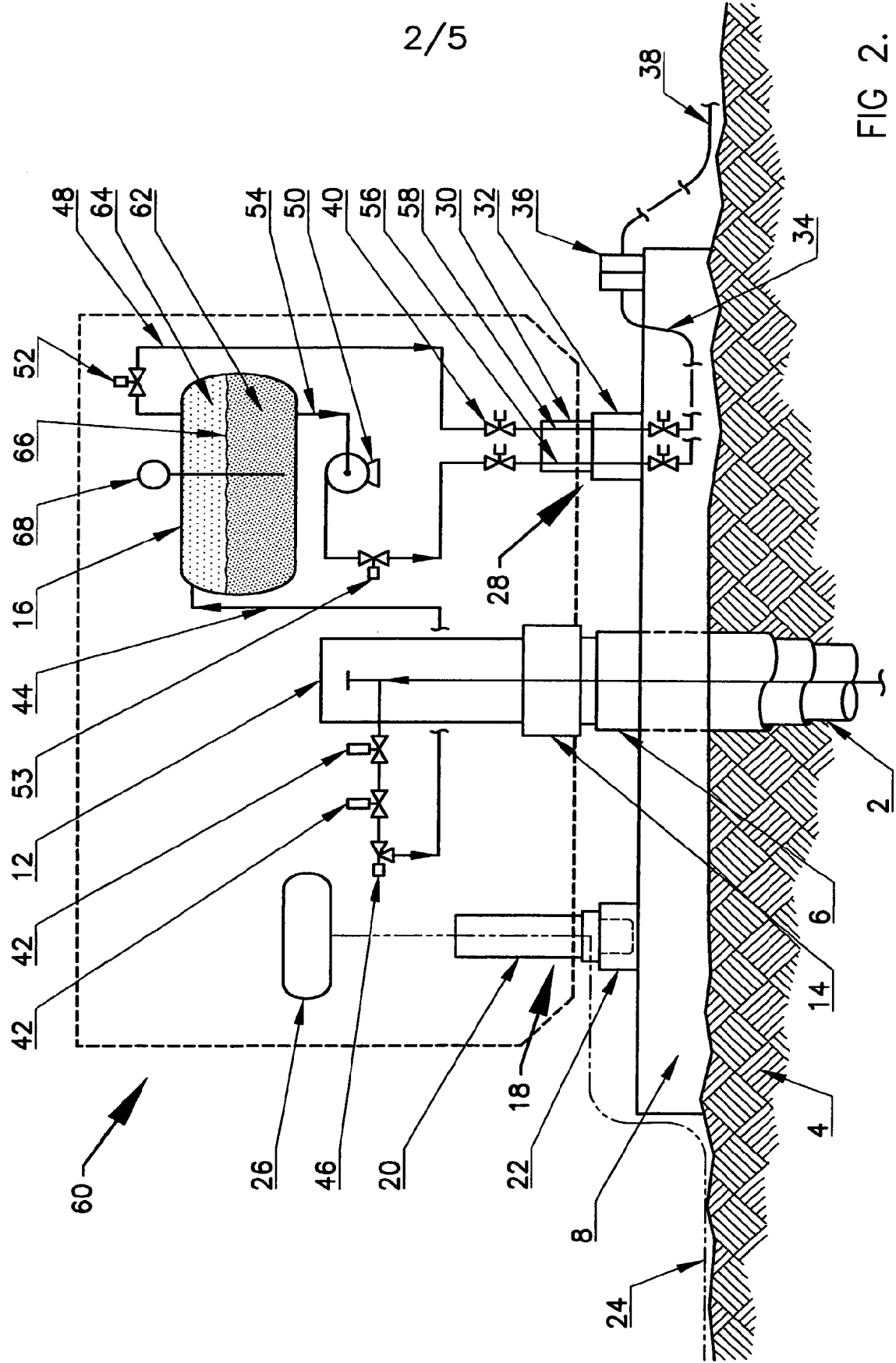
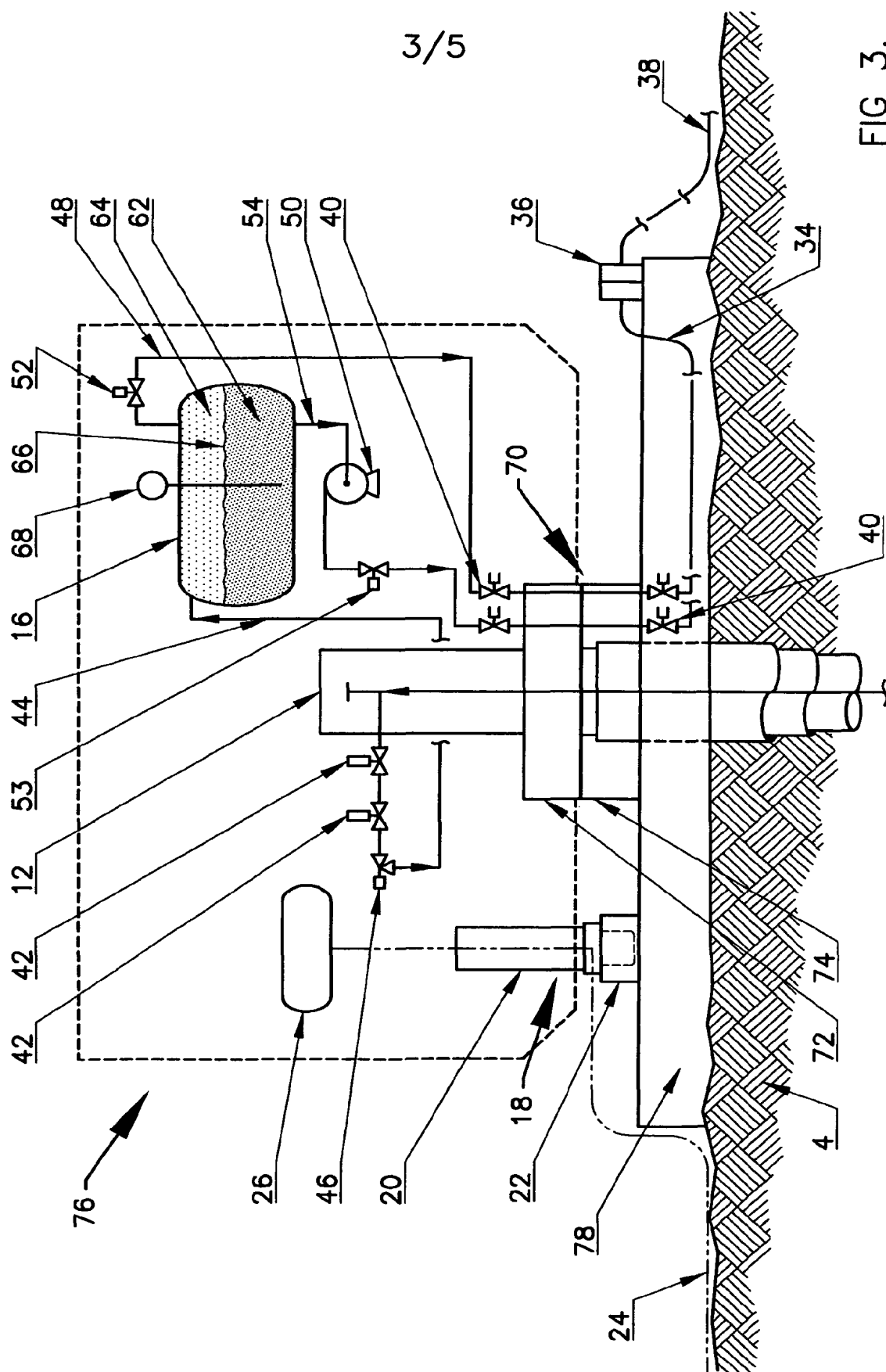


FIG 2.

FIG 3.



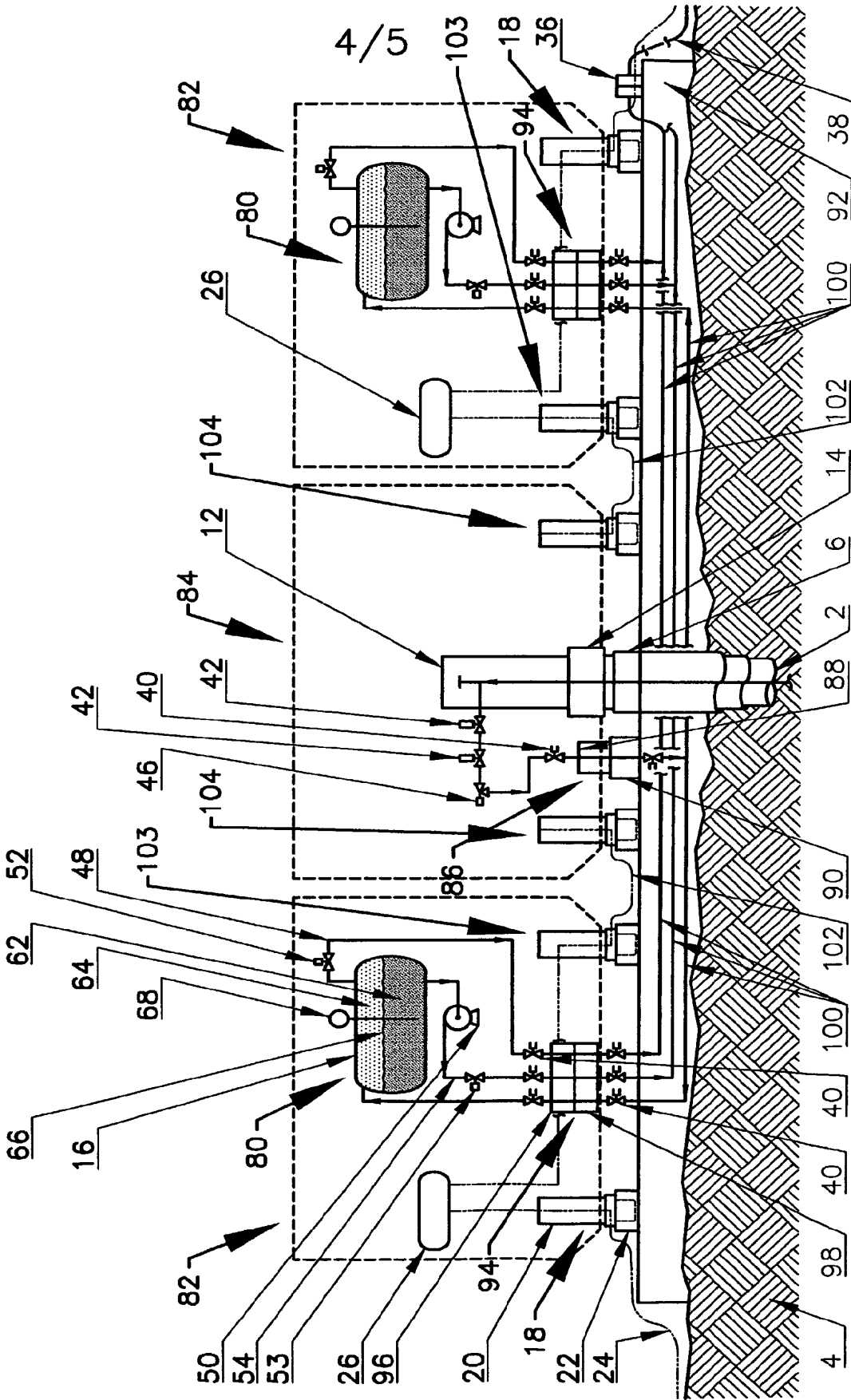


FIG 4.

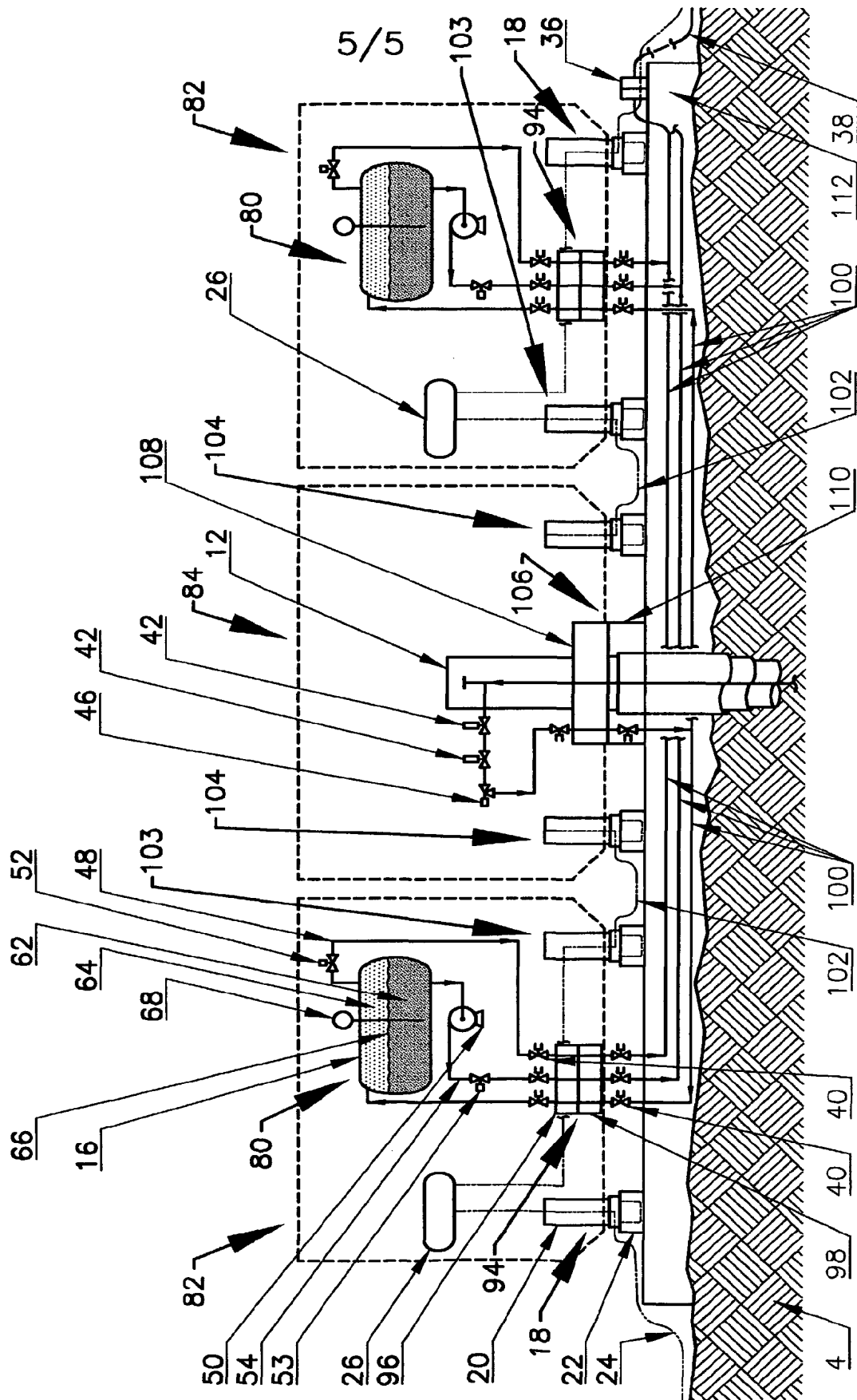


FIG 5.

# INTERNATIONAL SEARCH REPORT

International application No

PCT/GB 02/04625

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 E21B43/36 E21B43/017 E21B33/038

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	page 21, line 12 - line 28; figures 22-24,29-31	9-11, 14-19
Y	page 22, line 9 - line 16 page 26, line 8 - line 19 page 27, line 4 - line 17 ---	
Y	WO 01 20128 A (ALPHA THAMES LTD ;APPLEFORD DAVID ERIC (GB); LANE BRIAN WILLIAM (G) 22 March 2001 (2001-03-22) claims 1,4,6,33; figure 2 ---	9-11, 14-19
A	EP 0 527 618 A (PETROLEO BRASILEIRO SA) 17 February 1993 (1993-02-17) See abstract figure 1 --- -/--	1,28



Further documents are listed in the continuation of box C.



Patent family members are listed in annex.

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Date of the actual completion of the international search

21 January 2003

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Name and mailing address of the ISA

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## INTERNATIONAL SEARCH REPORT

International Application No

PCT/GB 02/04625

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
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A	US 4 732 215 A (HOPPER HANS P) 22 March 1988 (1988-03-22) column 1, line 35 - line 44; claim 1; figure 14 -----	1,28

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